

FIG. 2

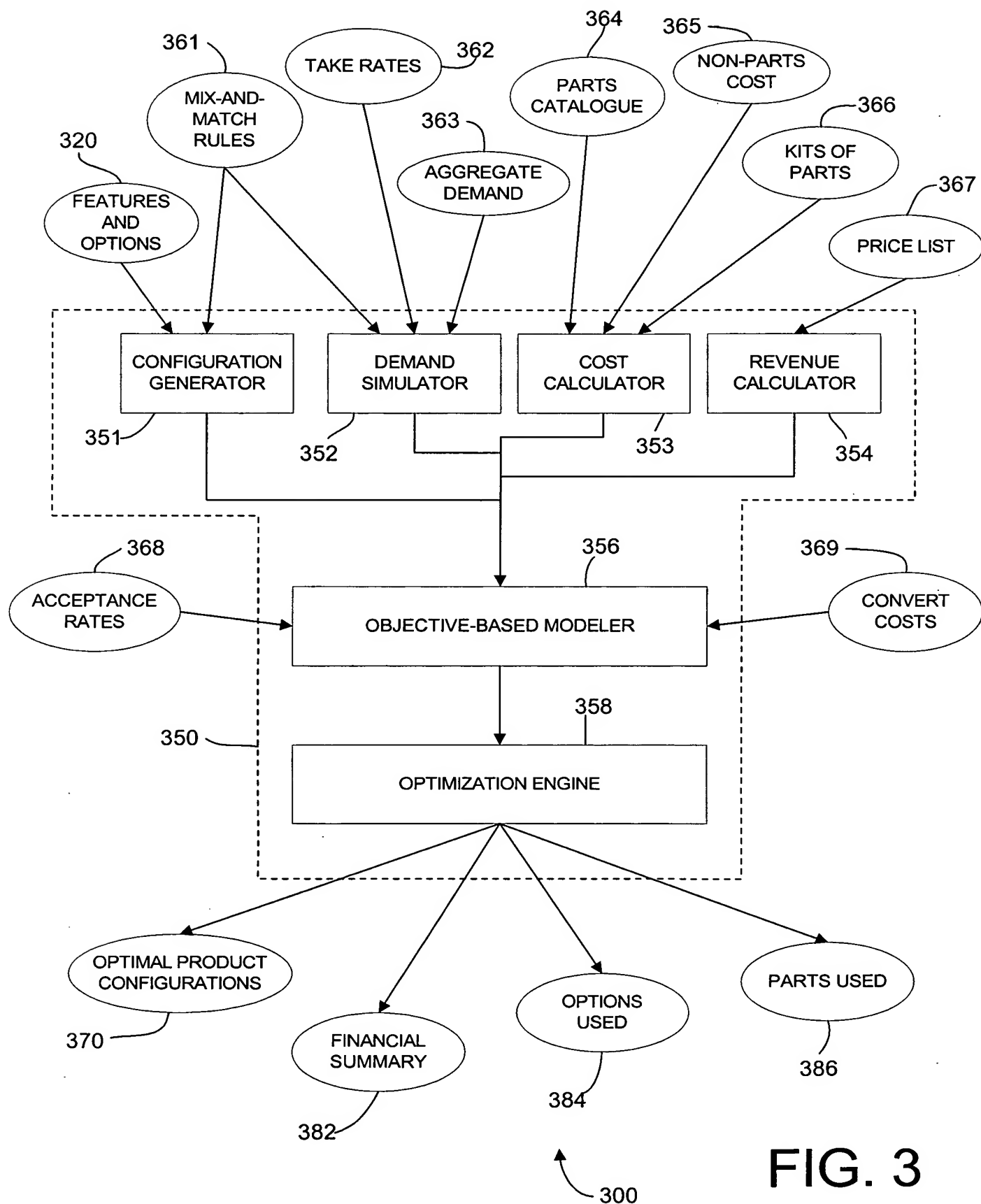


FIG. 4

400



Index	Feature	Number of Options	Option names
1	Model	6 options	Model 1 Model 2 Model 3 Model 4 Model 5 Model 6
2	Front Axle	2 options	2 wheel drive 4 wheel drive
3	Transmission	3 options	SST PRT HST
4	ROPS - Roll over Protection system	2 options	Fixed ROPS Folding ROPS
5	PTO - Power Take off	2 options	Less PTO Mid PTO
6	SCV - System Control valve	3 options	Less- SCV Dual-SCV Triple-SCV
7	Draft-links	2 options	Less draft links Flat bar draft links
8	Hitch	2 options	None Domestic hitch
9	Tires	20 options	2 wheel drive 4005 2 wheel drive 4015 2 wheel drive 4020 2 wheel drive 4030 4 wheel drive 4500 4 wheel drive 4505 4 wheel drive 4510 4 wheel drive 4515 4 wheel drive 4520 4 wheel drive 4525 4 wheel drive 4535 4 wheel drive 4540 4 wheel drive 4545 4 wheel drive 4550 4 wheel drive 4555 4 wheel drive 4556 4 wheel drive 4560 4 wheel drive 4565 4 wheel drive 4570 4 wheel drive 4575

FIG. 5

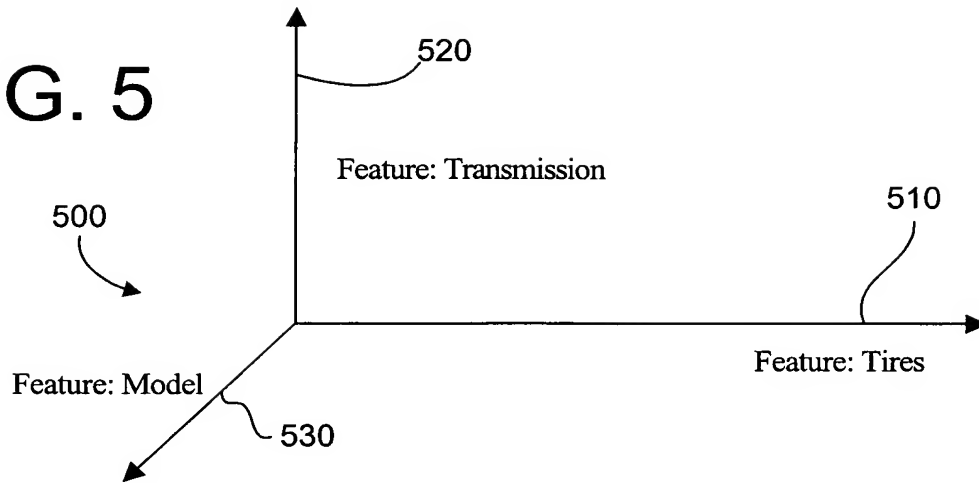


FIG. 12

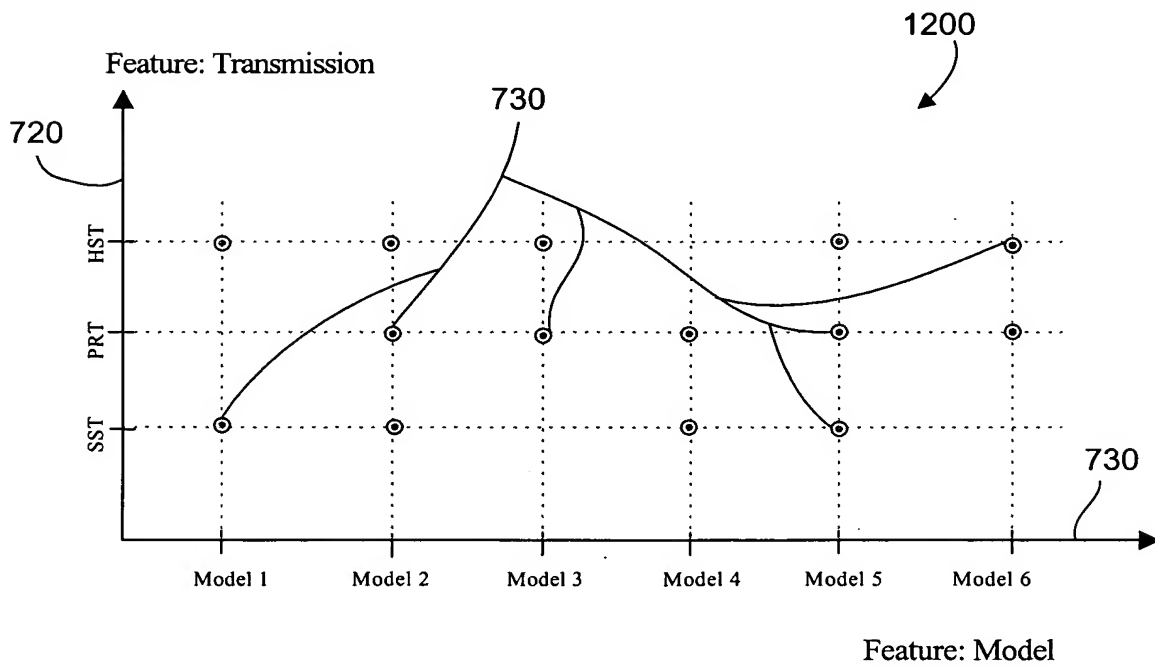


FIG. 6

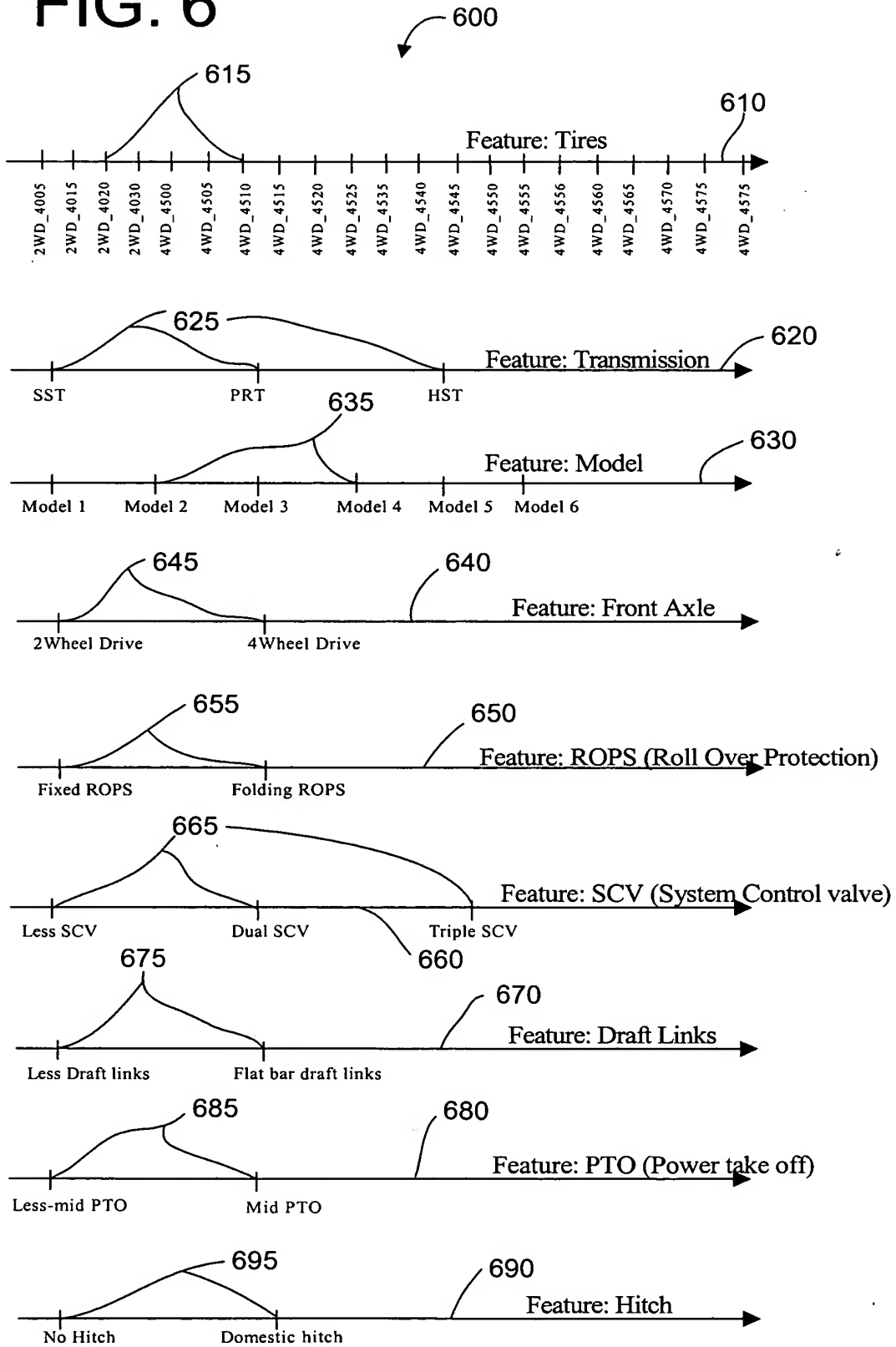


FIG. 7

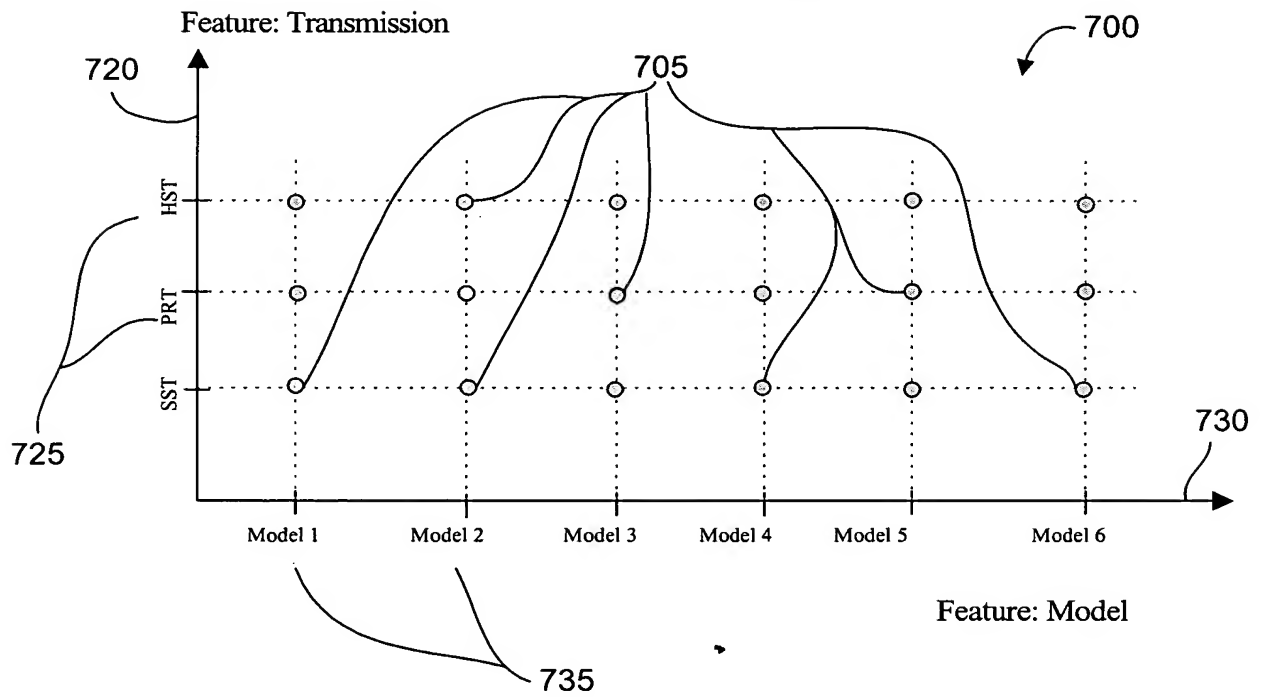


FIG. 8

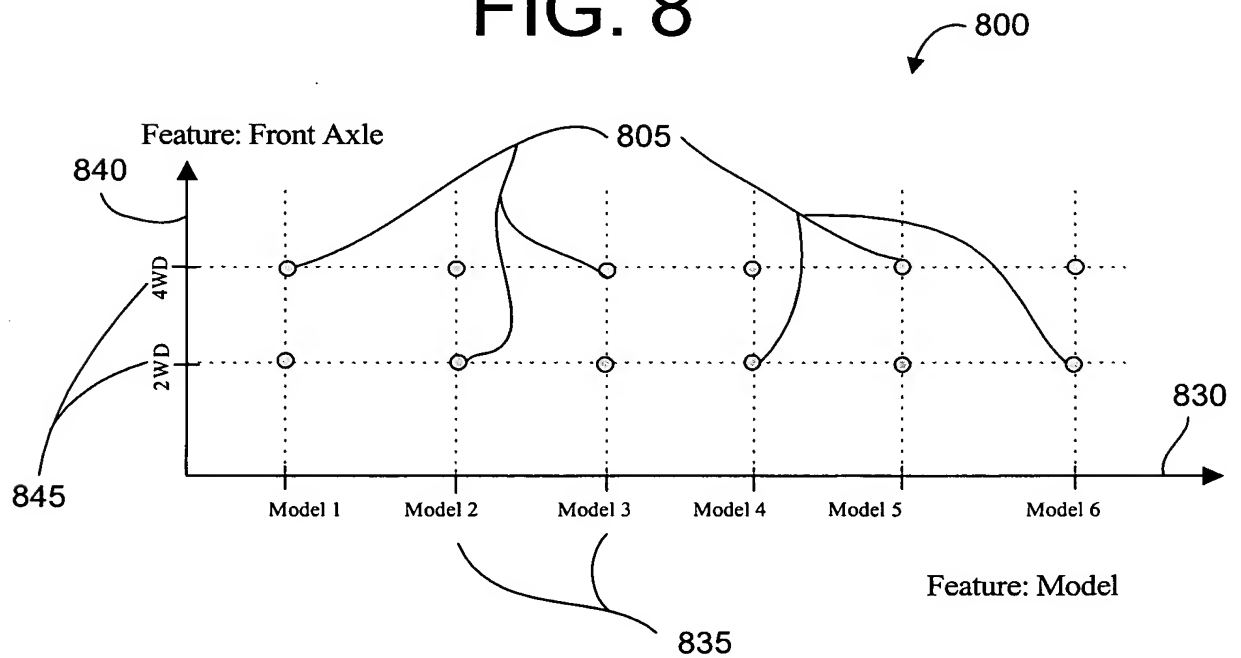


FIG. 9

900

Index	Feature 1	Option 1	Relationship	Feature 2	Option 2	Translation
1	A	x	NE	B	y	If feature A is at option level x, then feature B cannot be at option level y
2	A	x	EQ	B	y	If feature A is at option level x, then feature B must be at option level y
3	A	x	EE	B	y	Feature A can be at option level x, if and only if feature B is at option level y
4	A	x	OR	B	y	If feature A is at option level x, then feature B must be at option level y or z
	A	x	OR	B	z	

FIG. 10a

1000

Model	Model 3	EQ	Front Axle	4WD
Model	Model 6	EQ	Front Axle	4WD
Model	Model 1	OR	Transmission	SST
Model	Model 1	OR	Transmission	HST
Model	Model 3	OR	Transmission	PRT
Model	Model 3	OR	Transmission	HST
Model	Model 4	OR	Transmission	SST
Model	Model 4	OR	Transmission	PRT
Model	Model 6	OR	Transmission	PRT
Model	Model 6	OR	Transmission	HST
Model	Model 4	NE	PTO	Mid_PTO
Model	Model 5	NE	PTO	Mid_PTO
Model	Model 6	NE	PTO	Mid_PTO
Tires	2WD_4005	EQ	Model	Model_1
Tires	2WD_4015	OR	Model	Model_1
Tires	2WD_4015	OR	Model	Model_2
Tires	2WD_4020	EQ	Model	Model_2
Tires	2WD_4030	EQ	Model	Model_4
Tires	4WD_4500	EQ	Model	Model_1
Tires	4WD_4505	OR	Model	Model_1
Tires	4WD_4510	OR	Model	Model_1
Tires	4WD_4515	OR	Model	Model_2
Tires	4WD_4520	OR	Model	Model_2
Tires	4WD_4520	OR	Model	Model_3
Tires	4WD_4525	OR	Model	Model_1

FIG. 10b

1000
↙

Tires	4WD 4525	OR	Model	Model 2
Tires	4WD 4525	OR	Model	Model 3
Tires	4WD 4535	OR	Model	Model 2
Tires	4WD 4535	OR	Model	Model 3
Tires	4WD 4540	OR	Model	Model 4
Tires	4WD 4540	OR	Model	Model 5
Tires	4WD 4540	OR	Model	Model 6
Tires	4WD 4545	OR	Model	Model 4
Tires	4WD 4550	OR	Model	Model 5
Tires	4WD 4550	OR	Model	Model 6
Tires	4WD 4555	OR	Model	Model 4
Tires	4WD 4555	OR	Model	Model 5
Tires	4WD 4556	OR	Model	Model 6
Tires	4WD 4560	OR	Model	Model 4
Tires	4WD 4560	OR	Model	Model 5
Tires	4WD 4560	OR	Model	Model 6
Tires	4WD 4565	OR	Model	Model 4
Tires	4WD 4565	OR	Model	Model 5
Tires	4WD 4565	OR	Model	Model 6
Tires	4WD 4570	OR	Model	Model 1
Tires	4WD 4570	OR	Model	Model 2
Tires	4WD 4570	OR	Model	Model 3
Tires	4WD 4575	OR	Model	Model 2
Tires	4WD 4575	OR	Model	Model 3
Tires	2WD 4005	EQ	Front Axle	2WD
Tires	2WD 4015	EQ	Front Axle	2WD
Tires	2WD 4020	EQ	Front Axle	2WD
Tires	2WD 4030	EQ	Front Axle	2WD
Tires	4WD 4500	EQ	Front Axle	4WD
Tires	4WD 4505	EQ	Front Axle	4WD
Tires	4WD 4510	EQ	Front Axle	4WD
Tires	4WD 4515	EQ	Front Axle	4WD
Tires	4WD 4520	EQ	Front Axle	4WD
Tires	4WD 4525	EQ	Front Axle	4WD
Tires	4WD 4535	EQ	Front Axle	4WD
Tires	4WD 4540	EQ	Front Axle	4WD
Tires	4WD 4545	EQ	Front Axle	4WD
Tires	4WD 4550	EQ	Front Axle	4WD
Tires	4WD 4555	EQ	Front Axle	4WD
Tires	4WD 4556	EQ	Front Axle	4WD
Tires	4WD 4560	EQ	Front Axle	4WD
Tires	4WD 4565	EQ	Front Axle	4WD
Tires	4WD 4570	EQ	Front Axle	4WD
Tires	4WD 4575	EQ	Front Axle	4WD

FIG. 11

1100
↙

Rule Name	Feature 1	Feature 2	Yes/No
rule1	Model	Model_1	yes
	Front_Axle	2WD	yes
	Transmission	SST	yes
	PTO	Mid_PTO	yes
rule2	Model	Model_2	yes
	Front_Axle	2WD	yes
	Transmission	SST	yes
	PTO	Mid_PTO	yes
rule3	Model	Model_4	yes
	Transmission	SST	yes
	Front_Axle	4WD	yes
rule4	Model	Model_4	yes
	Transmission	PRT	yes
	Front_Axle	2WD	yes
rule5	Model	Model_5	yes
	Transmission	SST	yes
	Front_Axle	4WD	yes
rule6	Model	Model_5	yes
	Transmission	PRT	yes
	Front_Axle	2WD	yes
rule7	Model	Model_5	yes
	Transmission	HST	yes
	Front_Axle	2WD	yes
rule8	Model	Model_2	yes
	Transmission	PRT	yes
	Front_Axle	2WD	yes

FIG. 13

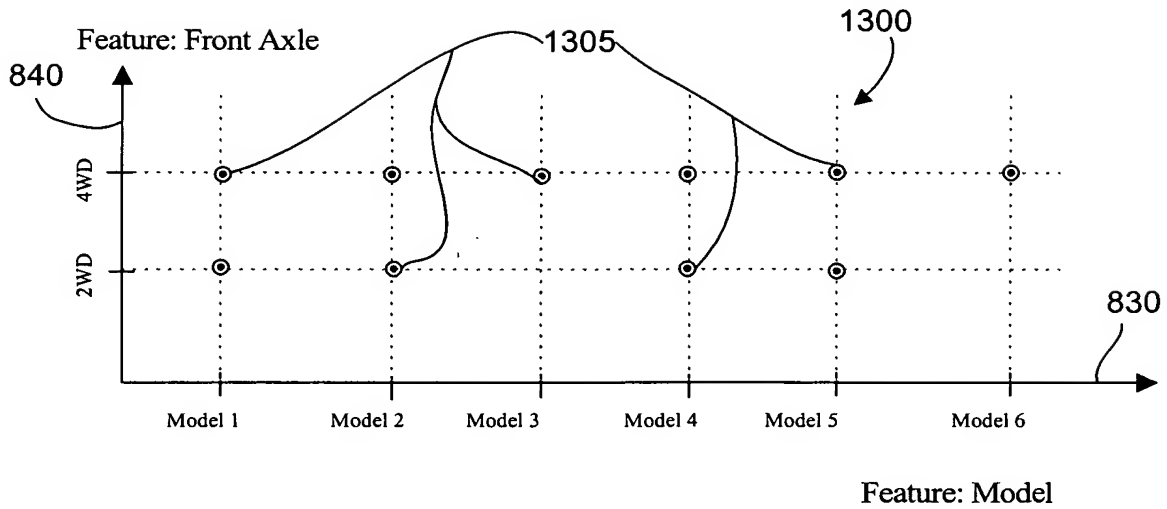


FIG. 34

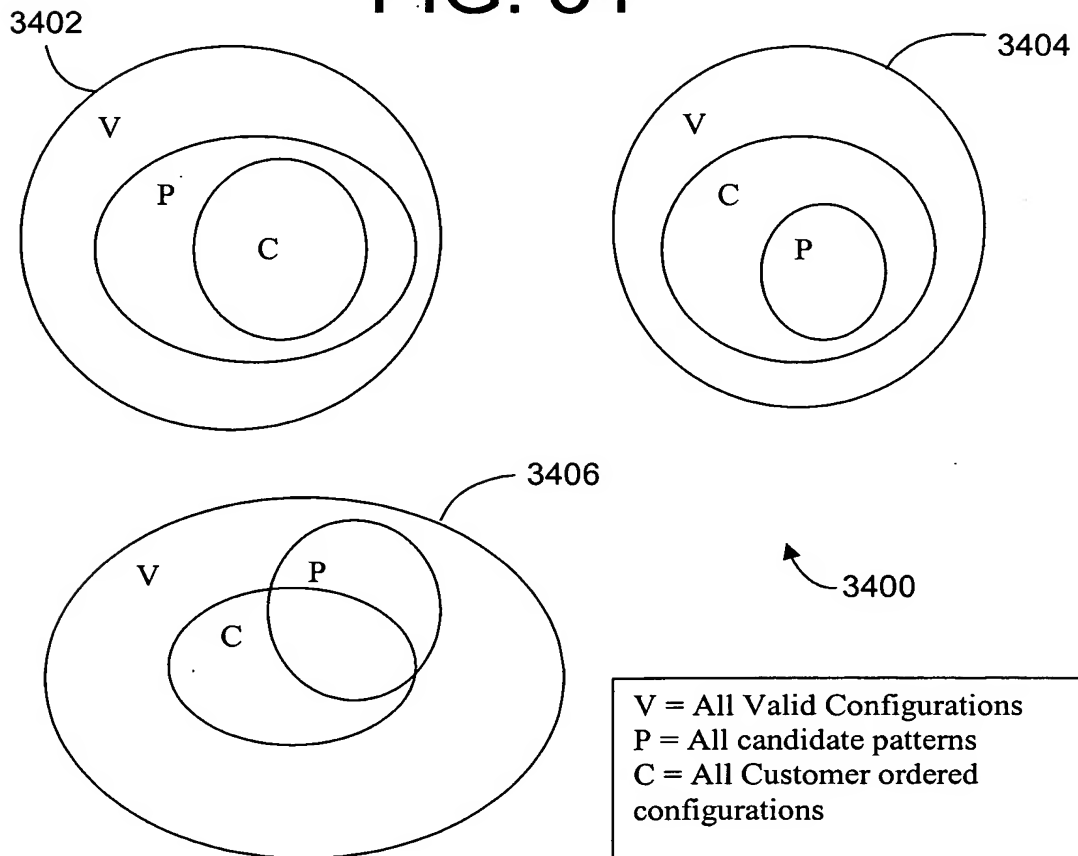


FIG. 14

1400

Part number	Quantity required
YZ18125	1
LVA11680	1
LVU12736	1
M137828	2
14M7298	2
19M7867	2
LVA11219	1
LVA11349	1
LVA11542	1
LVA11543	1

⋮

FIG. 15

1500

Part number	Unit cost
14M7298	0.02
19M7867	0.05
LVA11219	3.47
LVA11349	4.52
LVA11542	3.72
LVA11543	2.90
LVA11680	5.32
LVU12736	6.52
M137828	0.11
YZ18125	2805.62

⋮

FIG. 16

1600

Kit	Mask	Feature	Option	Y/N
KIT276	1	Transmission	SST	Yes
KIT276	1	Model	Model_1	Yes
KIT276	1	Front_Axle	4WD	Yes
KIT276	1	PTO	Mid_PTO	No
KIT276	2	Transmission	SST	Yes
KIT276	2	Model	Model_2	Yes
KIT276	2	Front_Axle	4WD	Yes
KIT276	2	PTO	Mid_PTO	No

FIG. 17

1700
↘

Feature	Option	1	2	3	4	5	6
Model	Model_1	15169	0	0	0	0	0
Model	Model_2	0	16339	0	0	0	0
Model	Model_3	0	0	19359	0	0	0
Model	Model_4	0	0	0	21279	0	0
Model	Model_5	0	0	0	0	22939	0
Model	Model_6	0	0	0	0	0	24709
Front_Axle	2WD	-1110	-1110	0	-1850	-2235	0
Front_Axle	4WD	0	0	0	0	0	0
Transmission	SST	0	0	0	-1200	-1200	0
Transmission	PRT	0	1200	0	0	0	0
Transmission	HST	2400	2400	1200	0	1200	1200
ROPS	Fixed	-170	-170	-170	-170	-170	-170
ROPS	Folding	0	0	0	0	0	0
PTO	Mid_PTO	390	390	390	0	0	0
SCV	Dual	700	700	700	700	700	700
SCV	Triple	950	950	950	950	950	950
Draft_Links	Less	-700	-700	-700	-630	-630	-630
Draft_Links	Flat_Bar	0	0	0	0	0	0
Hitch	Domestic	220	220	220	220	220	220
Tires	2WD_4005	90	0	0	0	0	0
Tires	2WD_4015	0	-95	0	0	0	0
Tires	2WD_4020	0	15	0	0	0	0
Tires	2WD_4030	0	0	0	-150	0	0
Tires	4WD_4500	0	0	0	0	0	0
Tires	4WD_4505	90	0	0	0	0	0
Tires	4WD_4510	210	0	0	0	0	0
Tires	4WD_4515	0	200	200	0	0	0
Tires	4WD_4520	0	400	400	0	0	0
Tires	4WD_4525	95	0	0	0	0	0
Tires	4WD_4535	0	220	220	0	0	0
Tires	4WD_4540	0	0	0	365	180	170
Tires	4WD_4545	0	0	0	0	0	0
Tires	4WD_4550	0	0	0	0	10	0
Tires	4WD_4555	0	0	0	185	0	0
Tires	4WD_4556	0	0	0	0	0	128
Tires	4WD_4560	0	0	0	595	410	400
Tires	4WD_4565	0	0	0	1610	1425	1415
Tires	4WD_4570	1295	1200	1200	0	0	0
Tires	4WD_4575	0	450	450	0	0	0

FIG. 18 ¹⁸⁰⁰

Model	Model 1	0.1391
Model	Model 2	0.3325
Model	Model 3	0.2034
Model	Model 4	0.0855
Model	Model 5	0.1034
Model	Model 6	0.1361

FIG. 19 ¹⁹⁰⁰

Feature	Option	Model					
		1	2	3	4	5	6
Front_Axle	2WD	0.0500	0.0370	0.0000	0.0520	0.0180	0.0000
Front_Axle	4WD	0.9500	0.9630	1.0000	0.9480	0.9820	1.0000
Transmission	SST	0.2060	0.0870	0.0000	0.0520	0.0180	0.0000
Transmission	PRT	0.0000	0.2460	0.1860	0.9480	0.4510	0.4270
Transmission	HST	0.7940	0.6670	0.8140	0.0000	0.5310	0.5730
ROPS	Fixed	0.3210	0.2270	0.1810	0.1600	0.1360	0.0820
ROPS	Folding	0.6790	0.7730	0.8190	0.8400	0.8640	0.9180
PTO	Less_PTO	0.5130	0.7340	0.5860	1.0000	1.0000	1.0000
PTO	Mid_PTO	0.4870	0.2660	0.4140	0.0000	0.0000	0.0000
SCV	Less_SCV	0.0660	0.0610	0.0180	0.0450	0.0180	0.0160
SCV	Dual_SCV	0.8450	0.8360	0.8590	0.8930	0.8320	0.8130
SCV	Triple_SCV	0.0890	0.1030	0.1230	0.0620	0.1500	0.1710
Draft_Links	Less_Draft	0.0020	0.0040	0.0040	0.0370	0.0130	0.0297
Draft_Links	Flat_Bar	0.9980	0.9960	0.9960	0.9630	0.9870	0.9703
Hitch	Domestic	0.0240	0.0500	0.0600	0.0450	0.0270	0.0570
Tires	2WD_4005	0.0420	0.0000	0.0000	0.0000	0.0000	0.0000
Tires	2WD_4015	0.0080	0.0260	0.0000	0.0000	0.0000	0.0000
Tires	2WD_4020	0.0000	0.0150	0.0000	0.0000	0.0000	0.0000
Tires	2WD_4030	0.0000	0.0000	0.0000	0.0518	0.0323	0.0000
Tires	4WD_4500	0.0260	0.0000	0.0000	0.0000	0.0000	0.0000
Tires	4WD_4505	0.3570	0.0000	0.0000	0.0000	0.0000	0.0000
Tires	4WD_4510	0.4840	0.0000	0.0000	0.0000	0.0000	0.0000
Tires	4WD_4515	0.0000	0.6030	0.5840	0.0000	0.0000	0.0000
Tires	4WD_4520	0.0000	0.1550	0.2560	0.0000	0.0000	0.0000
Tires	4WD_4525	0.0800	0.0600	0.0370	0.0000	0.0000	0.0000
Tires	4WD_4535	0.0000	0.1090	0.0740	0.0000	0.0000	0.0000
Tires	4WD_4540	0.0000	0.0000	0.0000	0.0755	0.1885	0.1533
Tires	4WD_4545	0.0000	0.0000	0.0000	0.1238	0.0000	0.0000
Tires	4WD_4550	0.0000	0.0000	0.0000	0.0000	0.0865	0.0853
Tires	4WD_4555	0.0000	0.0000	0.0000	0.1445	0.1113	0.0000
Tires	4WD_4556	0.0000	0.0000	0.0000	0.0000	0.0000	0.1023
Tires	4WD_4560	0.0000	0.0000	0.0000	0.6028	0.5680	0.6260
Tires	4WD_4565	0.0000	0.0000	0.0000	0.0018	0.0135	0.0333
Tires	4WD_4570	0.0030	0.0030	0.0160	0.0000	0.0000	0.0000
Tires	4WD_4575	0.0000	0.0290	0.0330	0.0000	0.0000	0.0000

FIG. 20

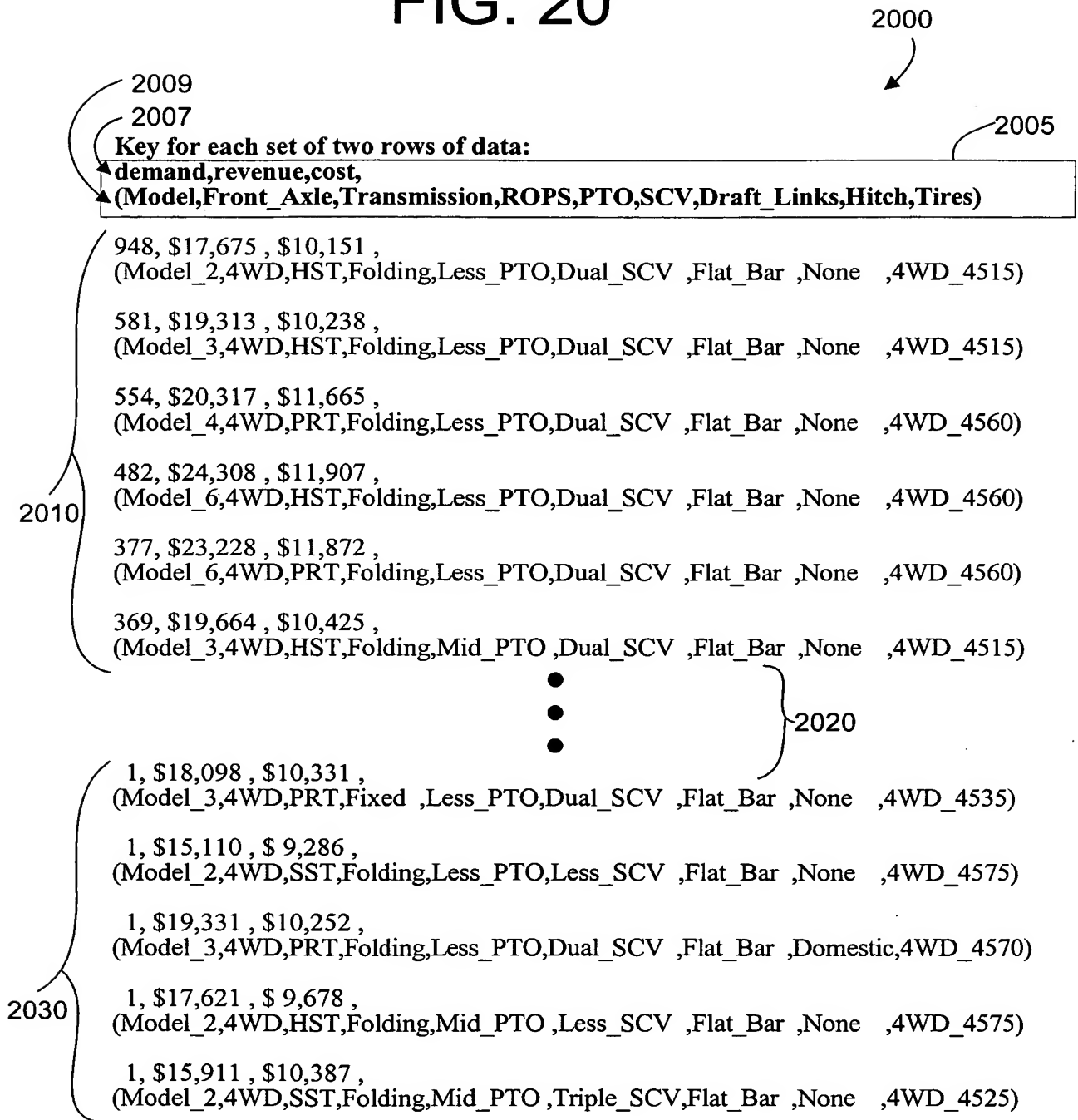


FIG. 21 ²¹⁰⁰

UPGRADE	L ss_SCV	Dual_SCV	Triple_SCV
Less_SCV	1	0	0
Dual_SCV	1	1	0
Triple_SCV	1	1	1

FIG. 22 ²²⁰⁰

UPGRADE	SST	PRT	HST
SST	1	0	0
PRT	0	1	0
HST	0	0	1

FIG. 23 ²³⁰⁰

CONVERT	SST	PRT	HST
SST	1	0	0
PRT	0	1	0
HST	0	0	1

FIG. 24 ²⁴⁰⁰

CONVERT cost	SST	PRT	HST
SST	0	INF	INF
PRT	INF	0	INF
HST	INF	INF	0

FIG. 25 ²⁵⁰⁰

ACCEPT probability	SST	PRT	HST
SST	1	0 - (2504)	0
PRT	0.4 - (2502)	1	0.2
HST	0	0.2	1

FIG. 26 

UPGRADE	Less_PTO	Mid_PTO
Less_PTO	1	0
Mid_PTO	1	1

FIG. 27 

UPGRADE	Less_Draft_Links	Flat_Bar_Draft_Links
Less_Draft_Links	1	0
Flat_Bar_Draft_Links	1	1

FIG. 28 

ACCEPT probability	2WD	4WD
2WD	1	0.2
4WD	0.5	1

FIG. 29 

ACCEPT probability	Fixed_ROPS	Folding_ROPS
Fixed_ROPS	1	0.5
Folding_ROPS	0.95	1

FIG. 30 

ACCEPT probability	Less_PTO	Mid_PTO
Less_PTO	1	0.5
Mid_PTO	0.5	1

FIG. 31 

ACCEPT probability	Less_SCV	Dual_SCV	Triple_SCV
Less_SCV	1	0.375	0
Dual_SCV	0.25	1	0.85
Triple_SCV	0.25	0.375	1

FIG. 32

3200
↘

ACCEPT probability	Less_Draft_Links	Flat_Bar_Draft_Links
Less_Draft_Links	1	0
Flat_Bar_Draft_Links	0.95	1

FIG. 33

3300
↘

ACCEPT probability	None	Domestic_Hitch
None	1	0.8
Domestic_Hitch	0.5	1

FIG. 35

3500
↘

d(i) = the demand for configuration i in units, where i is in C.

convert(i,j) = cost of converting from pattern j to configuration i,
where i is in C and j is in COMPETE(i).

prob(i,j) = probability that a customer who wants configuration i will
accept pattern j, where i is in C and j is in COMPETE(i).

c(i,j) = cost per unit if configuration i is assigned to pattern j,
where i is in C and j is in COMPETE(i).

r(i,j) = revenue per unit if configuration i is assigned to pattern j,
where i is in C and j is in COMPETE(i).

x(i,j) = 1 if configuration i is assigned to pattern j in the solution;
0 otherwise,
where i is in C, and j is in COMPETE(i).

y(j) = 1 if pattern j is chosen as a winner in the solution;
0 otherwise,
where j is in P.

FIG. 36

3600



MODEL (P1)

Maximize the Objective Function Over x and y:

$$\sum_{i \in C} \sum_{j \in COMPETE(i)} d(i) * (r(i, j) - c(i, j)) * x(i, j) \quad \leftarrow 3605$$

Subject to:

Constraint Set 1:

$$\sum_{j \in COMPETE(i)} x(i, j) \leq 1 \quad \leftarrow 3610$$

For i in C,

Constraint Set 2:

$$x(i, j) \leq y(j) \quad \leftarrow 3620$$

For i in C, j in COMPLETE(i)

Constraint Set 3:

$$\sum_{j \in P} y(j) \leq r \quad \leftarrow 3630$$

FIG. 37

3700

MODEL (P2)

Maximize the Objective Function Over x and y:

$$\sum_{i \in C} \sum_{j \in COMPETE(i)} d(i) * (r(i, j) - c(i, j)) * x(i, j) - G * (r - 1) \quad 3705$$

Subject to:

Constraint Set 1:

$$\sum_{j \in COMPETE(i)} x(i, j) \leq 1 \quad 3710$$

For i in C,

Constraint Set 2:

$$x(i, j) \leq y(j) \quad 3720$$

For i in C, j in COMPLETE(i)

Constraint Set 3:

$$\sum_{j \in P} y(j) - r = 0 \quad 3730$$

FIG. 38

3800

MODEL (LP2)

Maximize the Objective Function Over x , y and r :

3805

$$\sum_{i \in C} \sum_{j \in \text{COMPETE}(i)} d(i) * (r(i, j) - c(i, j)) * x(i, j) - G * (r - 1)$$

Subject to:

Constraint Set 1:

$$\sum_{j \in \text{COMPETE}(i)} x(i, j) \leq 1$$

3810

For i in C ,

Constraint Set 2:

$$x(i, j) \leq y(j)$$

3820

For i in C , j in $\text{COMPLETE}(i)$

Constraint Set 3:

$$\sum_{j \in P} y(j) = r$$

3830

Constraint Set 4:

$$0 \leq x(i, j) \leq 1$$

3840

For i in C , j in $\text{COMPLETE}(i)$

Constraint Set 5:

$$0 \leq y(j) \leq 1$$

3850

For j in P .

FIG. 39

3900

Lagrangian Function

$$L(\pi) = \max(x, y, r) \sum_{i \in C} \sum_{j \in \text{COMPLETE}(i)} d(i) * (r(i, j) - c(i, j)) * x(i, j) \\ - G * (r - 1) + \sum_{i \in C} \pi(i) * (1 - \sum_{j \in \text{COMPLETE}(i)} x(i, j))$$

3905

Subject to:

Constraint Set 1:

$$x(i, j) \leq y(j)$$

For i in C, j in COMPLETE(i)

3910

Constraint Set 2:

$$\sum_{j \in P} y(j) - r = 0$$

3920

Constraint Set 3:

$$0 \leq x(i, j) \leq 1$$

For i in C, j in COMPLETE(i)

3930

Constraint Set 4:

$$0 \leq y(j) \leq 1$$

For j in P.

3940

FIG. 40

Lagrangian Function - simplified

$$L(\pi) = G + \sum_{i \in C} \pi(i) + \max(x, y, r)$$

$$\sum_{i \in C} \sum_{j \in \text{COMPLETE}(i)} (d(i) * r(i, j) - d(i) * c(i, j) - \pi(i)) * x(i, j)$$

Subject to:

Constraint Set 1:

$$x(i, j) \leq y(j)$$

For i in C, j in COMPLETE(i)

Constraint Set 2:

$$\sum_{j \in P} y(j) - r = 0$$

Constraint Set 3:

$$0 \leq x(i, j) \leq 1$$

For i in C, j in COMPLETE(i)

Constraint Set 4:

$$0 \leq y(j) \leq 1$$

For j in P.

4000

4005

4010

4020

4030

4040

MODEL (D2)

4100

FIG. 41

$$\min(\pi \geq 0)L(\pi)$$

FIG. 42

4200

$$\sigma_j(\pi) = \sum_{i \in \text{CAPTURE}(j)} \max\{d(i) * r(i, j) - d(i) * c(i, j) - \pi(i), 0\}$$

4300

FIG. 43

$$P^* = \{j \in P \mid \sigma_j(\pi) \geq G\}$$

$$r^* = \text{number_of_elements}(P^*)$$

FIG. 44

4400

$$L(\pi) = G + \sum_{i \in C} \pi(i) + \sum_{j \in P^*} \sigma_j(\pi) - G * r^*$$

4500

FIG. 45

$$\pi_i^{k+1} = \pi_i^k - \lambda^k * (1 - \sum_{j \in \text{COMPETE}(i)} x^*(i, j))$$

For all i in C

FIG. 46

4600

$$x^*(i,j)=1 \quad \text{IF} \quad d(i)*r(i,j)-d(i)*c(i,j)-\pi(i)>0$$

$$x^*(i,j)=0 \quad \text{IF} \quad d(i)*r(i,j)-d(i)*c(i,j)-\pi(i)\leq 0$$

$$y^*(j) = 1 \quad \text{IF} \quad \sigma_j(\pi) \geq G$$

$$y^*(j) = 0 \quad \text{IF} \quad \sigma_j(\pi) < G$$

FIG. 47

4700

Step 0: Set $t=0$, and choose $P(t)$ as a subset of V .

Step 1: Solve $(P2(t))$ to get a solution.

$$(x^t, y^t, \pi^t)$$

4710

Step 2: Find a pattern k in $(V - P)$ such that:

$$\sigma_k(\pi^t) = \sum_{i \in \text{CAPTURE}(k)} \max \{d(i)*r(i,k) - d(i)*c(i,k) - \pi^t(i), 0\} \geq G$$

4720

If there is no such pattern k , then we are done.

Step 3: Set $P(t+1) = P(t) + \{k\}$. Set $t=t+1$. Go to step 1.

FIG. 48

Winning Pattern	Production	Revenu	Cost	Configuration
Pattern # 151	347.34375 units	\$14,822	\$9,770	Model_1,4WD,SST,Folding,Mid_PTO,Dual_SCV,Flat_Bar,None,4WD_4510

4804

4800

4900

FIG. 49

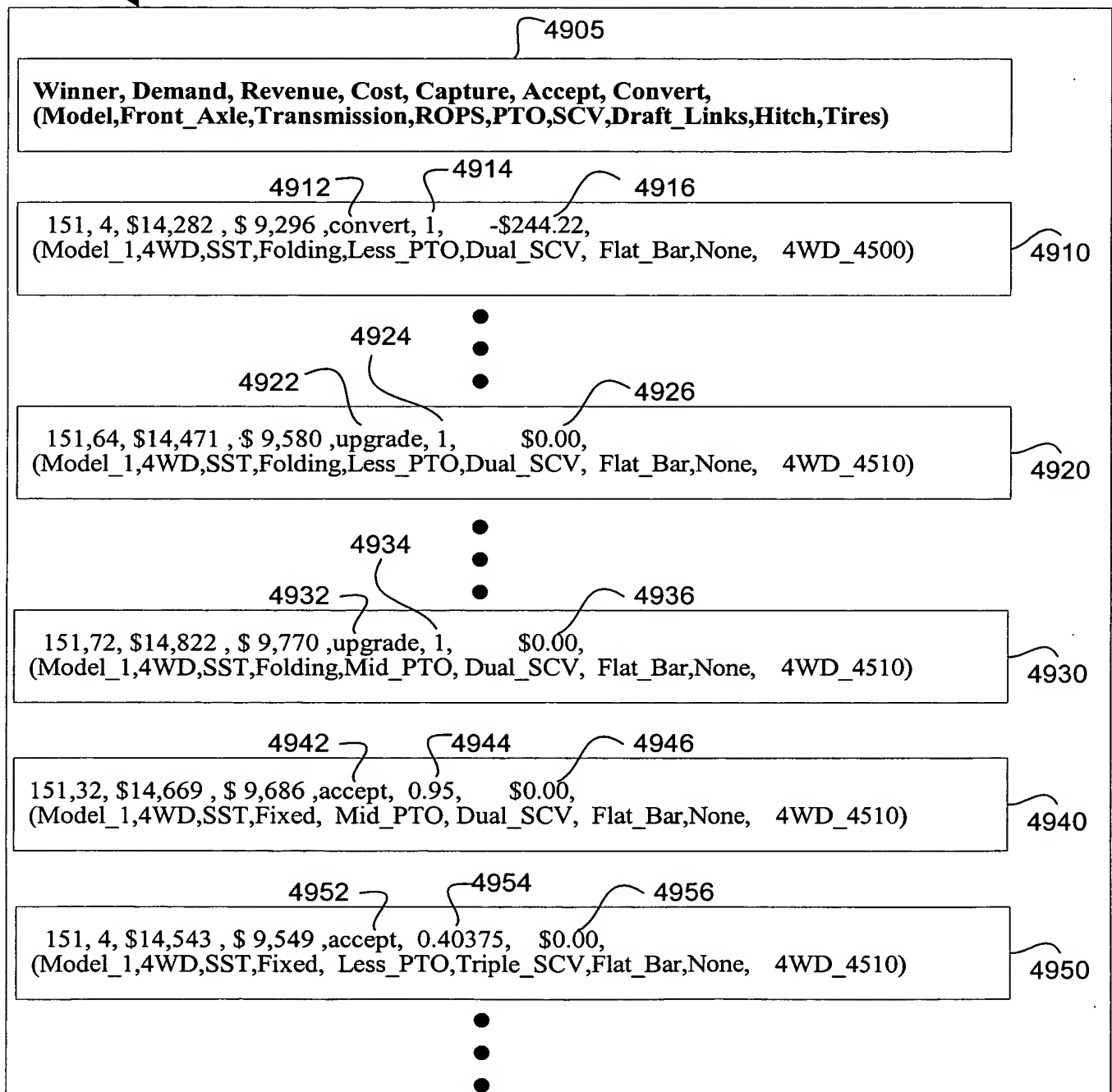


FIG. 50

